RE-BUILDING & REPAIR WELDING OF FORGING DIES

1.0 Introduction

Forging is one of the most important manufacturing processes for steel products. In the forging industry, the cost of forging dies is the single most important variable affecting the cost of forged products. These costs can be reduced by minimizing the use of costly die steels and by extending the lifetime of forging dies with the use of suitable weld metal.

Enhancement of Die life not only extends the lifetime of forging dies but it improves the productivity as well. Traditionally, dies in the forging industry are prepared using expensive hardened and tempered die steel. Die steel forging dies soon begin to wear and require reworking to extend their lifetime. Re-building of dies thus offers a proven and reliable repair service which is an alternative to disposal of too thin to work forging dies.

Thus fabrication of a new die and re-building of worn-out dies encompass the major recurring activities in any forging shop. During the forging operation, dies get worn out for the continuous exposure of heat & metal to metal abrasion and become over sized. For making any new die and also revamping the worn out dies, the cavity is buttered with suitable deposition. The composition & characteristics of the deposits vary on the size, type and expectations of impressions from the die.

2.0 Die-rebuilding

Cavities of worn out dies are gouged by carbon-arc-gouging process. The machined dies are then preheated to about 300–350°C prior to welding. Generally, the weld metal is deposited either by SMAW or by FCAW process and the rebuilding is done manually.

During the weld metal deposition necessary care is taken to make the weld deposit free from slag inclusion and/ or porosity. This is of utmost important in any dies because, even any tiny pin-hole porosity will give an impression of the defect in the forged component which needs to be machined & finished. The quality of the deposits thus becomes extremely important. After the re-building operation, the dies are stress relieved at 500-600°C temperature for 1 hour/inch thickness and subsequently machined to the required shape for the forging operation.

The weld deposition is done either by Layer welding or Flood welding. The process depends on the size of the die block and the size of the forging. Flood welding is faster and often better than layering. However, it is not recommended when the base material is H-11. Electrodes are better for layering & and flooding deep impressions and wires are good for layering as well as flooding larger & shallower impressions.

3.0 Few common Mold steel and Chromium hot work tool & die steel

AISI	UNS No	%C	%Cr	%Mo	%W	%V	%Ni
P2	T51602	0.07	2.00	0.20	-	-	0.50
P3	T51603	0.10	0.60	-	-	-	1.25
P4	T51604	0.07	5.00	0.75	-	-	-
P5	T51605	0.1	2.25	-	-	-	-
P6	T51606	0.1	1.5	-	-	-	3.5
P20	T51620	0.35	1.7	0.4	-	-	-
H11	T20811	0.35	5.00	1.50	-	0.40	-
H12	T20812	0.35	5.00	1.50	1.50	0.40	-
H13	T20813	0.35	5.00	1.50		1.00	-
H14	T20814	0.40	5.00	-	5.00	-	-
D2	T30402	1.50	12.00	1.00	-	1.00	-
D3	T30403	2.25	12.00	-	-	-	-
D4	T30404	2.25	12.00	1.00	-	-	-
D5	T30405	1.50	12.00	1.00	-	-	-
D7	T30407	2.15- 2.50	11.5- 13.5	0.70-1.20	-	3.80- 4.40	Co=3.0

DIN	%C	%Cr	%Mo	%Si	%Mn	%V	%Ni
2714	0.50-0.60	1.0-1.2	0.40-0.55	0.10-0.40	0.65-0.95	0.07-0.12	1.5-1.8

4.0 Steps for Die-Welding procedures

4.1 Pre-inspection:

The job is visually inspected for the location of die repair. In case of doubt, heating of the suspected area can be done with oxy-acetylene torch.

4.2 Removal of Cracks:

It is necessary that all cracks are completely removed prior to welding. Otherwise, the crack will surface after the re-building or machining operation and sometimes after it is put into service (forging of few pieces).

4.3 Gouging or Scarfing to remove the cracks:

Gouging electrodes are commonly used and scarfing can be done with an oxygen-Acetylene torch. No preheating is required for standard die steel while scarfing but H-11 materials must be preheated to 260°C.

4.4 Selection of welding materials:

- Type 540 low alloy steel (Ni-Cr-Mo alloyed, hardness 38-42 HRC) is the best choice when the machining after welding is done by milling.
- Type 535 low alloy steel (Ni-Cr-Mo alloyed, hardness 35-38 HRC) is preferred when tensile strength is low (less than 180 ksi).
- Type 9650 is recommended for small forgings - hammer dies and
- Type 9580 for small forgings - press dies.

4.5 Preheating & Welding:

- H-11 material – is preheated to 425°C and same inter-pass temperature is maintained until repairs are completed.
- Standard die steels – are preheated to 375°C and same inter-pass temperature is maintained until repairs are completed.

4.6 Post-heating & Tempering:

- After completion of welding, dies are allowed to slowly cool to 150°C or below.
- Stress relief or tempering is done at 550-600°C for one hour/ inch of thickness.
- For localized repairs (small areas), preheating is done as above and peening is done after weld deposition. The weld deposit is covered with asbestos to allow slow cooling to avoid post-weld heat treatment.

5.0 Welding Process & Procedures

5.1 Welding processes

Common welding processes used for repair welding of dies are as follows.

- GTAW, gas tungsten arc welding (TIG);
- SMAW, shielded metal arc welding (stick); and
- GMAW, gas metal arc welding (MIG)

TIG welding is used for small but critical deposits where the job requires a total control of heat and the volume of weld metal. It is also used to precisely fix the part of a die impression. Typical example of TIG welding is trim blade repair. The trimmers wear very rapidly. Usually TIG-welding is done with a Stellite surface onto the cutting edge of the trimmers.

The stick process is used mainly for repairs in very deep impressions or cavities, where welding guns are difficult to reach.

The majority of welding across the world on die re-building is done with the MIG process. Different sizes of MIG wires, 1.6mm to 3.2mm are commonly used for various applications. Generally, 1.6mm wire is used for overlaying works, 2.4mm wires are used for depositing the first alloy in the bottom of an impression, and also for capping impressions or where large amounts of weld metals are required.

5.2 Welding procedure

Any die re-building by stick or MIG process is done by two techniques – a) Layer or Overlay welding & b) Flood welding.

One after the other welding run is used for layer welding and a multiple layer build up is done for higher thicknesses. But in case of flood welding, the weld metal is filled on top of the die as if the liquid metal is poured on the die cavity. Before a die can be flood-welded, its surface preparation is very important. The surface of the entire impression and all visible defects are removed. The first alloy or bottom layers are deposited with hand guns; then the die is put on a welding manipulator station to finish the job using a remote-controlled gun with higher diameter welding wire. Flood welding gives the ability to apply the weld deposit much faster.

Manipulator welding involves using a water-cooled gun or torch where the operator sits a couple feet away from the heat. The gun operates at very high current (500-600 amps) with 2.4mm wire. Such welding is not done with a hand-held gun that works right over the welded area and would be very difficult for the operator.

5.3 Temperature control

Controlling the temperature of the die block before, during, and after welding is one of the most important factors in dealing with die re-building & surfacing applications.

Before welding, the die block is slowly heated to a specific temperature, typically a minimum of 425°C (800°F). Heating is done by oxy-acetylene torch, in an electric furnace or by electric pads.

Often to avoid the heat loss, the die is recommended to hold in an electric furnace during welding with only the weld area exposed for access. This approach maintains the die block at the 425°C temperature throughout the welding process. After a die block has been welded, the weld deposit area is hotter than the rest of that die block, so dies are still hold in the preheat furnace to equalize the temperature after welding.

Once the die temperature becomes uniform the die is allowed to cool in a controlled-cooling area where the rate of cooling is properly controlled. Slow-cooling of the dies to the required temperature prior to stress relieving is advisable to avoid localized stress concentration.

Stress relief heat treatment is done next. Though some of alloys have different stress relief requirements, the temperature commonly varies within 550 to 600°C. The rate of heating & rate of cooling is controlled to 50-75°C per hour maximum. The duration of holding depends on the thickness of the die and is selected as 1hr/25mm of thickness.

5.4 Effects of process variables

Preheating increases ductility in the base metal, reduces thermal shock to the base metal from arc welding temperatures, and retards the solidification rate of weld metal. All these effects reduce the possibility of die cracking.

Post-heating equalizes the temperature of the weld metal and base metal. This is important because the dies shrink as they cool down. They do not shrink at the same rate and these differences promote the formation of stresses that can lead to cracking.

Tempering removes welding stresses, induces toughness into the heat-affected zone, and induces toughness into the weld metal, without necessarily reducing hardness.

Another operation most effectively contribute to the quality of weld deposit is "Peening". Immediately after the weld metal is deposited, while cooling it is peened with a tool similar to a mini jack hammer. The peening process introduces compressive residual stresses and counteracts the tendency of the weld metal to shrink and tear away from the die metal. The peening device is mounted on a pneumatic tool so the operator has to apply very little pressure to peen, making it easier to thoroughly clean the slag after welding and also peen a weld deposit simultaneously.

6.0 Welding consumables

All widely used welding consumables for die-rebuilding applications are available in our product range. The categories of products include both MMAW or stick electrode and GMAW or FCAW products. The characteristic welding composition, hardness and scope of applications are detailed in the respective product leaflets.

6.1 MMAW electrodes (3.15 to 8.0 mm)

- D & H 535
- Dietherme HD
- D & H 9580
- D & H 9650

6.2 Flux cored wires (2.4 &2.8 mm)

1. Lotherme GS 535
2. Lotherme GS Dietherme HD
3. Lotherme GS 9580
4. Lotherme GS 9650

DIE-WELDING WORK ORDER SHEET

Name of the Die: Part no:

Number of forgings produced before failure:

Number of forgings produced under normal condition:

Description of the repair work: ____

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Die material:

Hardness of the die (as-received), HRC:

Type of consumables, MMAW/ FCAW:

Batch number: Size, mm:

Welding start date: Welding completion date:

Preheat temp, °C: Inter-pass temp, °C:

Quantity of deposit, kg: Duration of welding, hrs:

Observation of die after welding: ____

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Date, sent for tempering heat treatment:

Tempering temp, °C: Tempering time, hrs:

Double tempering, °C: Tempering time, hrs:

Hardness after tempering, HRC:

Hardness after double tempering, HRC:

Date, sent for machining after tempering heat treatment:

Observation of die after machining: ____

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Welded by: Supervised by: